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in this issue

Page

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Cybernetics and Agriculture[1]

By Harry C. Trelogan

THE GREATEST BOON from cybernetics[2] has been the stimulus given to man to formulate new concepts of how things are done and can be done--new views of the interrelationships of parts to a whole system. The new concepts lead to new ideas for conceiving of, and arranging, communications and control among the parts, between a central control and the parts, between external stimuli and central control, and between external stimuli and particular parts.[3] Cybernation opens opportunities for exploration of unconventional approaches to the achievement of given objectives, whether they be greater output, less costly operation, reduction of fatigue, speedier production, or combinations of these toward a primary objective judged as paramount, say the output of a new product or increased profitability.

Agriculture, bound with many long-established customs, is vulnerable to new approaches. In the not very distant past, farming was believed to be governed largely by nature. Farmers, work as hard as they might, simply had to work within the constraints of natural elements such as seasons, climates, weather, topographies, ecologies of undomesticated plants (weeds) and animals (insects) that were subject to little, if any, effective control. Also, in numerous instances, there was little advance communication or notification of what was going to occur (farmers' almanacs excepted, of course), despite intense interest in the factor concerned ("everybody talked about the weather, but nobody did anything about it"). Uncertainty, risk and other impediments induced by lack of control were accepted as facts of life the farmers had to adjust to--not adjust.

The late John Brewster probed into the implications for farming at length in his philosophical-economical way. He noted how mechanized factories brought production into controlled environments to permit output expansion of tremendous proportions. Why not farming? His first explanation of why even partially mechanized farms could not do so focused on the spatial requirements of farming. A farmer as an overseer had severe limitations on his ability to supervise many workers. Even with the horse and later the truck he was unable to exercise close enough observation, communication, and control to expand his operations much without serious loss of efficiency.

In view of this circumstance, it was clearly advantageous to have small farms, individually owned to instill the incentives for industry and care to maximize output. Each farmer reaped the fruits of his own industry and initiative. This fitted in well with the attitudinal, philosophical, and value concepts of the American Dream incorporating the Enterprise Creed, the Democratic Beliefs and the Work Ethics that Brewster explained so well in his writings.[4]

[1] Extracted from a talk presented at Cornell University's Conference on Impact of Mechanization, Automation, and Cybernation on Modern Agriculture, Ithaca, N.Y., December 11, 1967.

[2] Norbert Wiener. Cybernetics. The MIT Press, Cambridge, Mass., 2d ed., 1961. (Webster's New International Dictionary defines cybernetics as the "comparative study of the control system formed by the nervous system and brain and mechano-electrical communication systems, such as computing machines.")

[3] Leonard C. Silvern. Systems Analysis and Synthesis in Training and Education. Automated Education Handbook, Automated Education Center, Detroit, 1966.

[4] John M. Brewster. Technological advance and the future of the family farm. Jour. Farm Econ., Vol. 40, No. 5, Dec. 1958.

Later Brewster[5] put greater emphasis on another circumstance limiting the ability of farming to adapt to the factory system. That was the requisite sequential nature of the productive functions dictated by the seasonality of weather. This requirement circumscribed the opportunity for farm laborers to specialize in the performance of specific functions. Since farm production had to be spread out over time, it was not possible to perform successive production steps simultaneously so that crews of specialized workers could work continuously on specific tasks and maximize the use of their skills, as was done within the confines of a factory where their work could be synchronized to contribute most efficiently to the production of an end product. Instead, each farmer had to organize his productive resources so that he would have sufficient labor to perform one job after the other as each season progressed. The necessary communications and controls were lodged, for the most part, in the farmer himself as the manager of all operations throughout all seasons. His management skill reflected his ability to move from one function to the other from beginning to end of the production process at minimum cost.

Advances in mechanization adapted to farming enabled the farmer to extend his labor resource with the use of more capital. At first this development used animal power and later the greater power of steam engines and automotive equipment. But the problems of communications and control remained essentially the same and limited the farmers' managerial power because of the greater dependence upon personal observation and decision-making.

In general, farming has taken some advantage of the innovations coming out of each of the eras cited by Wiener in the gradual evolution of power developments. (He referred to the 18th century as the age of the clock, the 19th century as the age of steam, and the present age as that of servo mechanisms.) Except for the era of animal power, the adaptation of new power sources to farming has been tardy and less complete compared with commercial and industrial enterprises. The relative tardiness is particularly notable with respect to electronic power applied to communications and servo mechanisms in relatively small and continuous increments. Tremendously impressive and very frightening potentials for farm application remain for exploitation.

New Concepts Related to Farming

The impressive aspects pertain to the impact electronic power may have on men's concepts of farm production. Bringing cybernation to bear on the communication and control limitations of farm operations creates the potential for overcoming some of the space and time handicaps that Brewster saw so clearly. The great dependence upon relevant observations and judgments previously made by individual farm managers may now be replaced with precise measurements made by technicians that can be transposed into data, masses of which can now be transmitted, processed, and analyzed quickly at central points quite removed from the farming sites; so that specialized management skills need no longer be decentralized among millions of farm operators. Servo mechanisms may well be devised to use the feedback from even abrupt changes in weather to react promptly and flexibly to major contingencies. Mechanical and automotive power has already enhanced the ability to respond quickly to needed changes in resource inputs, particularly those previously requiring labor. Fatigue becomes far less limiting compared with animal and manual power.

Environmental controls likewise have been introduced to a remarkable degree and are subject to conscious and deliberate employment. Forewarnings of impending changes in the natural environment are now commonplace. They are not yet early enough or accurate enough to satisfy--they are unlikely ever to satisfy--but they are beyond past experiences, hopes, and dreams.

One example of a developing work closely akin to the responsibilities of the Statistical Reporting Service may serve to suggest cybernetic applications of the future.

[5] John M. Brewster. Technological advance and the structure of American agriculture. Jour. Farm Econ., Vol. 29, No. 4, Part I, Nov. 1947. Also, The machine process in agriculture and industry. Jour. Farm Econ., Vol. 32, No. 1, Feb. 1950.

Crop and livestock estimating is fundamentally a communication and control function or mechanism. This is especially true as many businessmen and, to a lesser extent, farmers use the service. It can therefore be regarded as an example of cybernetics in a very crude, gross, and macro sense. The service can be conveived as an annual cycle of forecasts and estimates that begins with measurements and readings to alert a whole host of decision makers to agricultural supply portents in the season ahead. Reports of intentions to plant, intentions to breed, placements in poultry breeding flocks, hatcheries, and broiler chickenhouses, seed production and livestock inventories, are examples of such data. Subsequent data on actual acreages planted, cattle on feed, cows milked, and farm labor inputs provide information on the degree to which intentions or plans have been altered as a result of feedback within the system. Interim estimates of yields and production forecasts as the season progresses reflect the probable impact of contingencies related to weather, insects, diseases, and the like. Harvest estimates followed by stocks, utilization, and disappearance data and final revisions depict the realization of plans and give current supply indications. Crop and livestock estimating is one form of a communication and nervous system essential to the successful functioning of a capitalistic farming system characterized by numerous independent farmers served by numerous independent suppliers, handlers, and distributors.

Acquisition of data for crop and livestock estimates depended for literally a century on the mail questionnaire directed to literally millions of farmers and returned on the average by about one-third of them. The method was founded on the proposition that farms in the United States were sufficiently alike that a sample consisting of many farmers distributed throughout all parts of the country could be considered representative of all farms. The foundations of this method, which were reasonably sound when we had twice as many, and more diversified, farms, began to be eroded some three decades ago along with trends toward fewer, larger, more specialized farms. Today a large sample can no longer be regarded as a representative sample. Advances in statistical technology, particularly in probability sampling, have pointed the way toward the use of even smaller samples properly selected to obtain representative estimates. For several years the Statistical Reporting Service has been developing and introducing a system of area probability sampling to be associated with other data collection methods to obtain more reliable estimates. The central core of this system consists of some 17,000 segments of land comprising 0.6 percent of the total agricultural land area to provide foundation data on such items as land in farms, numbers of farms, acreages of principal crops, livestock inventories, farm labor, and wages.

In the design, allocation, and drawing of the probability samples upon which these foundation data are based, the computer performs a function roughly analogous to process or management control. The microsecond speed of the computer makes possible the solution of problems requiring thousands of iterations which can generate sample allocations which minimize cost, not for one but for a dozen items. Then the computer can be assigned the task of selecting a sample conforming to this allocation. Thus to the computer can be assigned the control, in the statistical sense, of the universe of sampling units from which the Statistical Reporting Service collects its data.

Obviously extreme care must be exercised in obtaining the data from a small sample to expand into estimates for the universe. Also, in view of the extremely high cost of the survey methods used to obtain such data--largely through personal interview--compared with the cost of mail questionnaires, exhaustive use must be made of the data. Since this is a multipurpose sample from which the data must be gathered and processed within short and rigid time schedules, access to electronic computer power is necessary.

Computer capabilities also make feasible the computation of standard errors from the sample data, thus providing the Crop Reporting Board with indications of the reliability of some sample data for the first time in history. This is a quality advantage that was not within the realm of possibility prior to the advent of probability sampling and high-speed electronic computers.

For the estimation of yields during the growing season in order to forecast production, the information obtained through the mail questionnaire

is necessarily based upon subjective appraisals of a rather imprecise nature. Questions have to be posed in terms farm respondents can comprehend. Answers have to be accepted in terms reasonably subject to interpretation. Consequently, early season crop queries refer to "percentage of normal," relying upon each farmer's own concept of normal; and midseason queries refer to probable yield this year compared with last year. Only at harvest time can we be more specific and ask for estimated yield per acre in definable units; e.g., bushels of shelled corn with 15.5 percent moisture.

To obtain objective yield estimates, novel and highly specific counts and measures and much smaller samples are employed. For example, objective counts and measurements of fruit are related to biological time, instead of fixed calendar dates, to fit mathematical models designed to forecast ultimate yield. Biological time alludes to intervals between the occurrence of natural phenomena, e.g., full bloom and fruiting, a shifting base from one year and location to another. The aggregate area from which wheat samples are measured to make national estimates of yield will approximate one-half acre and the harvested wheat amounts to less than 1,000 pounds. Electronic equipment solves the equations utilizing the data from each of many sample plots providing numerous and precise measurements.

These sketchy descriptions suffice to indicate the degree of departure from previously established systems used to acquire crop and livestock information; also to suggest the manner and extent to which cybernetic methods are being brought into play. At this stage of development and acceptance of the new methods with their attendant high costs, they are used only to reinforce and not to replace the older methods. The time may come when there is public acceptance of the vastly greater costs of the more precise estimates to permit full reliance upon them, but that is unlikely to occur soon. At the moment, procedures are being developed for multiple frame sampling. These procedures enable the estimators to incorporate, into a single probability sample design, samples from both list and area frames. The cost advantages of multiple frame designs arise from opportunities to collect some of the data by mail and to focus on small populations of interest. The intricacies of merging the results from the two samples into probability estimates will further test the computer.

All the costs cannot be expressed in monetary terms. Modern probability sampling increases our dependence upon cooperation from respondents. This incurs objections to invasion of privacy; objections that are minimized under present voluntary reporting systems.

Applications Facilitated by Integration

These objections can be eliminated in potential applications of these same methods to individual farming operations. Today we have in a number of States significant numbers of farmers reporting management data into central points for electronic analyses. In many instances these represent modern outgrowths of the old farm management analytical services conducted in agricultural colleges for research and demonstrational purposes. In general, the participating farmers can now receive individualized analytical results for which they are willing to submit data and to pay the price. Thus far they have been interested chiefly in getting back data that facilitate the preparation of tax returns. By comparison, they have shown relatively little interest in the use of these analyses for production planning and control. The opportunity is nevertheless there for far more detailed and continuous use for these purposes, especially if the operations are large enough to justify the expense. The justification can be more easily seen, the larger and the more dispersed the farming operations that are brought under unified and centralized management.

It takes little stretch of the imagination to visualize how these computer analyses can be applied to horizontally integrated farming operations to overcome space and time limitations stressed by Brewster. Where these impediments are less severe and other difficulties have been successfully overcome, as in huge cattle feeding lots, broiler chicken plants, and egg laying houses, the introduction of automation and cybernation is both startling and commonplace. But even in these instances the possibilities are far from being fully exploited.

Immediate opportunities awaiting exploitation abound as vertical integration of farming operations spreads into factor supply and product processing and distribution. One can visualize data intensively collected on farms, utilizing methods already employed for crop estimating and transmitted over radio equipment already installed in farm field trucks. The data would serve as computer inputs that can be translated and relayed to such diverse outlets as insecticide and herbicide suppliers, fertilizer applicators, aerial spraying outfits, and harvesting crews prepared to respond in accordance with contractual arrangements worked out well in advance of actual needs. Financial requirements likewise can be anticipated and geared to computer outputs, transmitted automatically to banking institutions which are prepared to provide credit in the amounts and at times needed. Field harvesters and packers can be alerted and scheduled on the basis of computer outputs that can at the same time give fairly precise orders for packaging supplies, transportation, refrigeration, grading, and storage services.

Some Occupational Requirements

Scientists are spending entire careers extracting the fuller meaning and implications of selected fragments of Norbert Wiener's ideas. Whole groups of the next generation of agriculturists are going to gain livelihoods from applications of cybernetics to agriculture viewed in the broad. Farms and farmers will constitute subsets in the analyses.

That consequence may not be particulary disturbing. The most frightening aspects of cybernation applied to farming stem from institutional, sociological, and conceptual impacts that appear likely to ensue. In the current agricultural statistics program of the Statistical Reporting Service increased difficulties are encountered in ascertaining what is a farm, what workers should be properly classified as either farm or agricultural labor, who can or will furnish reliable data on integrated farming operations, what can be reported as a valid price received by a "farmer" enveloped in an integrated enterprise, where can one ascertain prices paid in units and terms comparable with other farmers, how can contractual terms be converted to standardized prices suitable for aggregation and averaging. Identities of even the most basic elements underlying our reporting system will have to be reviewed and redefined. Many prospective answers to such questions violate logic based upon traditional concepts, some conflict with our sense of integrity, others impinge upon our sense of the ridiculous. These reactions are symptomatic of cultural shocks that are likely to pervade the whole fabric of American agriculture. They point up the fact that technological changes induced by cybernation will call for the reformulation of economic theories on which we rely for a rationalization of much of our work. Obviously, this cannot be done by any one agency or group, public or private, acting independently or in isolation. A lot of this adaptation of human intellectual concepts to oncoming technology is overdue, the intensity of need is growing at accelerating rates, and the abrasive interfaces with deepseated values and beliefs are proliferating.

Some research, academic, and educational institutions serving agriculture have their work cut out for them. Conferences, seminars, public dialog leading to the reformulation of economic theories, will bring these problems to the surface and expedite work on them. There will be a need to uncover genius in many quarters not only to capitalize on Dr. Wiener's genius, but also to clean up the debris left in his wake.

A Comparative Review of Some Firm Growth Models

By George D. Irwin

NATIONS, STATES, corporations, farm operators, and even a core of agricultural economists have the growth fever. Prominent among the symptoms in the last mentioned group are a freshet of computer-oriented models.

This article explores the growth features included in three types of models used in studies of recent vintage--multiperiod linear programming, recursive linear programming, and a family of simulator models--and then makes a summary comparison.[1] In the process, I hope to accomplish several things: (1) to touch on what is implied about growth in some recent efforts in comparative statics and identify some unresolved problems; (2) to review several types of models from the "early-finishers" among the current crop of growth projects, to see how they handle these problems; and (3) to make a few suggestions about how to use the growth concept in formulating research problems.

Growth Fundamentals

One of the mainstays of industrial economic life has long been growth and merger. Farming has seen some of this, but on a much lesser scale. Yet, with growing farm-nonfarm interdependence, it is at least conceivable that the dominant historical theme of the last half of the 20th century will be growth in size of production units.

[1] Case studies, production function analyses, or other econometric approaches may also have merit in studying growth. However, I restrict my assignment here to a discussion of the computer-oriented models, leaving the broader discussion for a time when my intellectual digestion has proceeded beyond its present state.

A fundamental issue in studying growth is the interrelating of the short run production theory, which involves at least some fixed resources, and the longer run investment theory, which varies them. The wedding of these two must necessarily recognize that, to paraphrase Boulding, the firm has a balance sheet as well as a production mechanism. The nature of the balance sheet items, in combination with the efficiency of the production mechanism in generating cash flows, are the interface with an off-farm capital market. This market, together with the rate at which the production mechanism generates residual funds internally and the rate of consumption withdrawal, determines a maximum for the investment process. Externalities such as off-farm growth rates in markets, resource supplies, and technology further constrain the environment.

In its simplest terms, the principle of growth is to acquire control of the services of additional productive resources by paying a price less than they will earn. The process of growth is, at its core, obtaining funds to purchase these resources, either internally or from external sources. All the other variables we might name--family consumption levels, profitability of the business, price and yield variability, lender attitudes, tax management, etc.--are merely the bounds within which the process can operate.

Thus, the two crucial aspects in considering growth are (1) the concept of the decision process used, and (2) the handling of internal and external flows of funds.

To sort through the details of various types of growth models, it may be useful to think in terms of the kinds of reports made annually to corporate stockholders. These are basically

the net worth, the profit-and-loss, and the cash flows statements.

In the context of planning within the usual framework of marginal economic theory, restrictions generally relate to the physical and financial balance sheets, and the objective function generally to the profit and loss. The third category, cash flows, is an amalgamation of the first two. It appears in the model as the activities and equations involving money. It has probably been the least adequate of any feature of past models, except perhaps for the failure to consider in greater detail borrowing capacity as an asset. Flows affect the balance sheet in the following period, and thus are a key to building in dynamics.

The job of growth researchers is to identify variables hypothesized to have significant influence on these accumulation processes, to test the hypotheses, and to use the results to mold conclusions. These conclusions may include, for example, (1) information for farmers, or (2) better estimates of the parameters of aggregate supply, or (3) recommendations for changes in farm credit structure.

This hypothesis testing can be done at many levels, varying from case studies in the field to the construction of elaborate computer models. Both an advantage of and a danger in the model approach is that the appropriate model obviously depends upon your conception of how farmer decisions are made. This itself is a researchable problem, and one of the facets that must develop as a part of firm growth research. Studies using the models may be either or a combination of two types: of the growth process, per se, in a mechanical sense and largely abstracted from human talents and goals; or of which firm grows and why, including all the human variables. It is also useful to distinguish, conceptually, between the kind of growth an individual operator makes in adjusting to a given technology, and that he makes in adjusting to changes in technology.

Use of Optimizing Models

In a broad sense, all models are optimizing and all are simulators. It is just a matter of how. But a narrower definition of each term will prove useful here. First, the familiar question--why optimizing? George Kuznets (20)[2] has made some interesting observations:

> Virtually all of the analytical concepts used in agricultural economics are derived or are derivable from one or another optimizing model . . . The great attractiveness of optimizing models, one might almost say their fatal charm, is their deductive fertility . . . the main point . . . observed relations between time series and between variables in cross section can be explained by micro models that are not of the optimizing variety.

Optimizing applies to single-goal mathematical models. The price paid for analytic convenience is the ruling out of some realism at the beginning. For this reason, the multiple-goal, nonanalytic approach we will distinguish as simulation has intrinsic appeal, if less deductive elegance (27). This article will consider both kinds of models.

It would not be fruitful to conduct a drumming-out ceremony for either type at our current stage of understanding. The important problem is to explore how each is able to describe or represent the situation we are interested in examining. Each of several approaches has unique features. Whether or not a particular combination is appropriate depends on the problem. To state it in another way, the kit of research tools does not contain one universal model for studying growth.

Comparative Static Supply-Adjustment Models

We can set the stage for examining the various models by asking: How have the usual comparative static frameworks of the regional supply-adjustment studies handled these problems? Ordinarily they started with a representative farm, which translates to the potentially growing firm. The first step was to "cash in" all livestock, and other assets, and place them in an investment capital fund. Land, on the other hand, was usually considered fixed.

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[2] Underscored numbers in parentheses refer to items in the References, p. 99.

Usually machinery was associated with the land. A matrix of production processes was set up, including various combinations of annual inputs and durables, such as buildings and breeding herds. The solution obtained was for some average year, say 5 to 10 years in the future.

A truncated form of the balance sheet served the limited function of setting up the initial resource restrictions. Its role in explaining liabilities and net worth and in the generation of funds from external sources was virtually ignored.[3] About the only way in which external capital was handled was via an assumed rate against which the assets could be pledged for borrowing. This may or may not have been augmented by an annual liquidity equation, depending on the study. The assets cashed in before the model run were assumed to be converted, over the time span, into the combination at the end, often involving completely different enterprises. Thus, the solution tells nothing about the process of getting to the new position, surely an item of great interest. A second feature was that during the period, it was assumed that the firm did not generate any funds internally which could be used to expand the business.[4] Yet the solution frequently showed large "net returns." Clearly, there are some difficulties in not knowing anything about the intermediate steps, the process of growth.

Growth Models

MULTIPERIOD LINEAR PROGRAMMING

Swanson model. In 1955, Earl Swanson (33) published what was probably the first linear programming model which, as he described it, "attempts to deal with the problem of planning over time. That is, more than one period of production is considered . . . a long run farm plan with a transition plan is . . . specified." The farm model was for 5 years ahead, with some activities continuing over the entire period, others representing the transition year only, and still others embracing all years following the transition. The model had an activity to transfer part of income from one year to the next, above a $5,000 minimum consumption and fixed cost allowance. One-half of the income above the minimum was made available to the business in the following year. The criterion function was maximum present value of the plan. Although primarily an enterprise choice model, investment in a grain combine was considered as an alternative. Interestingly, the word growth did not then get emphasized. The focus was on making models more realistic over time. Yet it is clearly an ancestor of more recent growth models.

Loftsgard-Heady model. About 4 years later, Loftsgard and Heady (21, 22) demonstrated a more detailed version of the multiperiod (they called it dynamic) linear programming model as an aid in farm and home planning. Their example allowed annual expansion of hog production on a fixed-acreage farm, and after livestock capacity was utilized it demonstrated internal generation of surplus funds.

The model involves basically a block diagonal matrix. That is, if activities and restrictions are arranged by years, the nonzero coefficients group diagonally. The only row overlapping is that net income for one year transfers to operating capital for the next year. The increase in operating capital between years is the difference between the net return for all activities and certain fixed charges and a household consumption allowance. The model was initiated with a given supply of operating capital. The amount available the following year was increased by the net return generated by the plan for the year, less living and fixed costs. The variable maximized was the sum of present value of net revenues from all production in all years, using a 6 percent discount rate.

The simplified structure of the model is illustrated in table 1. Note that the only entries off the diagonal block arrangement are in the capital row for the following year. The value entered is the sum of net revenue and operating capital, except that after the first year, the computation

[3] One study I am aware of, on Oklahoma dairy farms, did use a balance sheet to derive a more sophisticated supply-of-funds schedule. See Clark Edwards and H. W. Grubb (5).

[4] The study of Edwards and Grubb (5) assumed initial borrowing to make immediate adjustment and also estimated payback periods. It did not, however, consider the possibility of subsequent investments or increases in indebtedness.

Table 1.--Simplified version of the Loftsgard-Heady multiperiod linear programming farm planning model

Item	P_o	Year 1			Year 2			Year 3		
		Hogs	Beef	Fixed cost	Hogs	Beef	Fixed cost	Hogs	Beef	Fixed cost
Net revenue ...	max.	$\frac{60}{1.06}$	$\frac{36}{1.06}$	--	$\frac{60}{(1.06)^2}$	$\frac{36}{(1.06)^2}$	--	$\frac{60}{(1.06)^3}$	$\frac{36}{(1.06)^2}$	--
Year 1:										
Capital......	7,000	150	120	1						
Labor........	700	20	10	0						
Fixed cost...	3,600	0	0	1						
Year 2:										
Capital......	0	-210	-156	0	150	120	1			
Labor........	720				20	10	0			
Fixed cost...	4,000				0	0	1			
Year 3:										
Capital......	0				-210	-156	0	150	120	1
Labor........	750							20	10	0
Fixed cost...	3,900							0	0	1

Source: (22).

is made before the net revenue function is discounted. In complete detail, of course, the model had a large number of production activities, and a total of 8 years. By making the fixed charge row an equality, available capital in the first period is reduced by the amount of fixed costs and consumption--$3,600.[5] The remainder is available for allocation between hogs and beef. Each unit produced of either generates capital for the succeeding period, which starts at a zero capital level.

This simplified short-run example makes it easier to see the several parameters available to be manipulated for growth purposes: family consumption and fixed obligations, labor supply, price cycles, yield cycles, enlargement of the activity set with more farmer experience in later years, improvement of technical efficiency over time, or increases in initial capital supply.

What are some features one might like to alter in such a model for present purposes? (1) It depicts the short run; no land, building, or machinery investments are considered. (2) The external capital market is not considered. The capital transfer process assumes all owned funds. No borrowing, rental, or lease is considered. (3) No allowance is made for risk and uncertainty. (4) The goal is assumed to be maximization of the discounted sum of net revenue. (5) Social security and income taxes are omitted. (6) Consumption cannot be made a function of current or past years' income. Many of the same limitations apply to the models to be discussed below. Each, however, adds certain important dimensions to the analysis.

Irwin-Baker model. A further development emerges in a polyperiod model with explicit and detailed consideration of the external

[5] For the first year only, the row and column could be omitted from the computational matrix, and the fixed cost could be deducted from the initial capital supply. For later years, the row and column could be eliminated by entering the fixed cost as a negative P_0 value in the capital row, reversing the direction of the inequality sign, and then reversing the signs on all coefficients in the row (P_0 must be nonnegative). Answers would be the same, but interpretation would differ slightly, since the negative slack value would represent unused capital.

Table 2.--Simplified two-period structure of the Irwin-Baker programming model incorporating financial and production decisions

	Feeder cattle	Fertilize		Sell corn		Savings account	Transfer cash to funds for--				Transfer cash		Borrow for--				Repay loan		Carry-over loan
		Level 1	Level 2	Period I	Period II		Fert.	Cattle	Oper. I	Oper. II	Cash II	Profit	Fert.	Cattle	Oper. I	Oper. II	Oper. I	Oper. II	
	1 head	1 acre	1 acre	1 bushel	1 bushel	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
Objective	Gross	Gross	Gross									+1.0	-i	-i	-i	$-\frac{1}{2}i$	$\frac{1}{2}i$	-1.0	
Maximum loan																			
Period I													$(1+k_1)$[1]	$(1+k_2)$	$(1+k_3)$				
Period II													$(1+k_1)$	$(1+k_2)$	$(1+k_3)$	$(1+k_3)$			
Operating loan balance																			
Period I															-1.0		1.0		1.0
Period II																-1.0		1.0	
Cash Balance[2]																			
Period I						1.0	1.0	1.0	1.0		1.0								
Period II				-Price		-(1+i)				1.0	-1.0	1.0					1.0		
Total balance[3]																			
Fertilizer		Costs	Costs				-1.0						-1.0						
Cattle	Costs							-1.0						-1.0					
Operating I									-1.0						-1.0				
Operating II										-1.0						-1.0			
Labor input																			
Period I	Input	Input	Input																
Period II	Input	Input	Input																
Feedlot capacity	1.0																		
Corn acreage		1.0	1.0																
Corn inventory	Input	-Yield	-Yield	1.0	1.0														

[1] k_i is defined as a discount factor $\frac{\text{Maximum loan for cattle less maximum loan for the purpose}}{\text{Maximum loan for the purpose}}$

[2] Cash receipts less expenses in parts of business assumed fixed.

[3] Cash plus borrowing.

capital market (14, 15).[6] It is polyperiod only in the sense of having transfers among the four calendar quarters of a single year. No investment theory is involved. Further, the set of production activities is severely limited because of the nature of the problem being investigated.

The model is illustrated in table 2. This matrix, too, would exhibit the general block diagonal characteristic if we rearranged the various rows and columns into periods. As presented, it illustrates the components arranged functionally.

To understand the structure, we need to summarize the situation being studied: A farmer has made all decisions for a year except (1) how many cattle in excess of one carload he will feed, (2) at what level he will fertilize corn, and (3) how he will finance operating expense. He has been able to work out income flows to this point, and has found he has insufficient funds to meet operating expenses if he feeds additional cattle and fertilizes corn at the same time. He has gone to the bank with his financial and income statements, and has obtained a commitment that a certain number of dollars can be borrowed for each purpose, taken alone. His problem is to choose among the three purposes. Operating expense must be met, and thus has implicitly a very high marginal return. Fertilizer, in turn, returns more per dollar spent than feeder cattle.

To handle the problem of considering the purposes simultaneously, the concept of an asset called credit reserve was introduced. It is equal to the largest number of dollars that can be borrowed for any purpose, given the financial and income statements. In most cases this is the amount for feeder cattle. Maximum loans available for the other purposes are smaller. Interrelating is accomplished if we define a "discount" factor which measures the increased rate at which the other purposes use up the farmer's credit reserve. This shows the importance of the balance sheet concept and a method for bringing it into a production analysis.

Four quarters[7] were used, since operating expenses occur periodically, as budgeted and shown in the P_0 row, and it is possible to sell stored corn or to borrow to meet them. In addition, the fertilizer loan is required only for the growing season. The cash available equations specify the difference between income from sale of other crops and livestock and the family living expenses. The value for a period can represent a negative balance. It is possible to repay loans in any period in the model. Cattle sales contribute to cash in the final period, when sold, and the fertilizer contributes to profit in the amount of its marginal net yield contribution. Interest charges on initial loans assume they will be outstanding for the year. Thus "prepayment" during the year returns part of the interest charged with borrowing. Finally, an activity takes the net accumulated cash in period 4, including unused returns from cattle, and transfers them to the net returns function.

Rod Martin's model. Another contribution provides guidance on incorporating the longer run investment aspects of growth (23, 24). In fact, it used the optimal farm solution from a minimum resource study as a composite single activity called operating plan, defined on a per acre basis. All other activities were to invest in resources, or to handle the transfer of funds between years.

A two-period condensed version of the model is presented in table 3. The firm has some surplus resources, i.e., it is an established 426-acre farm, and all resources are at least adequate to allow the operating activity to come into the solution at a level of 426 acres. However, machinery capacity is available for up to 700 acres, and fixed costs are constant up to this size. Expansion may be by buying for cash, on mortgage, or by renting. The model assumes livestock must be purchased to maintain the present crop-livestock balance if acreage is increased. Such a requirement is necessary

[6] For subsequent applications of this type of model, see the following theses prepared under Dr. C. B. Baker at the University of Illinois: D. F. Neuman, Effects of Nonreal Estate Loan Policy of Primary Lenders in the Organization of Farms in Central Illinois, 1963; L. F. Rogers, Effects of Merchant Credit on Farm Organization, 1963; J. M. Vandeputte, Farm Mortgage Debt Management on Low Equity Dairy Farms, 1967; A. G. Smith, Alternative Strategies for Financing Growth of a Grain Farm, 1968.

[7] The simplified two-period version in table 2 is for illustration only.

Table 3.--Resource levels, activities, and restriction requirements of capital accumulation model

Item	Unit	Resource or restriction level	Operating activity	Land acquisition			Hire labor	Borrow capital	Buy equipment	Fixed cost	Buy livestock	Consume 25% of net returns	Save capital	Transfer reinv. capt. 1 to op. capt. 2
				Cash buy	Amortized loan	Rent land								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Prod. period 1:														
Land...........	ac.	426	-1.0	-1.0	-1.0	-1.0								
Labor..........	hr.	1,900	3.14											
Operating capt..	dol.	6,106	18.11	242.00	16.05	12.00	-1.0	-1.00	3.95	1.00	5.26	.25		
Collateral......	dol.	102,240			285.53		2.0							
Equipment.......	ac.	700	1.0						-1.0					
Livestk. Invest.	ac.	426	1.0								1.0			
Fixed cost......	dol.	4,532								1.0				
Net returns.....	dol.	0	-24.97	2.00	13.31	12.00	1.00	.06	2.79	.34		1.0		
Reinv. capt.....	dol.	6,106	-24.97	242.00	16.05	12.00	1.00	.06	3.95	1.0	5.26	.25	1.0	1.0
Prod. period 2:														
Land...........	ac.	426		-1.0	-1.0									
Labor..........	hr.	1,900												
Operating capt..	dol.	0			16.05				3.95					-1.0
Collateral......	dol.	102,240		-240.00	279.58									
Equipment.......	ac.	700												
Livestk. Invest.	ac.	426							-1.0					
Fixed cost......	dol.	4,532												
Net returns.....	dol.	0			13.16				2.72					
Reinv. capt.....	dol.	6,106	-24.97	242.00	32.10	12.00	1.00	.06	3.95	1.0	5.26	.25	-.04	
Subsequent time periods		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Objective function (net returns)			24.97	-2.00	-282.96	-12.00	-1.00	-.06	-73.22	-.34	0.0	0.0	.04	0.0

Source: (23).

because of the enterprise balance assumed in the coefficients of the operating activity. The model calls for $3,000 consumption base plus a marginal propensity to consume of 25 percent. Borrowing is limited to 50 percent of mortgage debt.

The relationship between years has three important aspects: (1) Land or machinery capacity added in any period is available for future periods, and creates loan collateral in those periods. (2) A reinvestment capital equation in the first year accumulates net capital generated, adds operating capital initially available, and subtracts the amounts committed for resource purchase, consumption, and saving. This amount is required and available in all succeeding periods, since the amount is also subtracted from the profit function. Hence, it can be inserted in the reinvestment capital row for succeeding years. (3) The only additional obligation if the firm operation remains unchanged the second year is for amortization of land and equipment loans. Thus only surplus reinvestment capital from the first period is transferred to the second to meet additional operating requirements.

The net returns equation insures that annual obligations on durables can be met. The particular objective function illustrated is to maximize net returns. The overall study examined six different objectives, but found little basis for choosing among them, since the structure of the model tended to overwhelm any differences among the functionals. A 30-year planning period was assumed, and several variations of the model were employed.

What are some of the desirable features of the model? (1) Investment in durables is considered. (2) Relationships to the external capital market are fairly explicit. Borrowing is allowed, based on equity and the type of asset to be purchased. (3) Several objectives are examined. (4) The consumption function is an explicit part of the model. (5) Both one-shot investment funds and annual liquidity requirements are specifically accounted for in the model. On the other hand, no opportunities for disinvestment and no risk elements are assumed.

S. R. Johnson's model. A model similar in many ways to Martin's brings the concept of risk into the analysis (17). Crop yields are assumed to consist of a base value (or average yield) plus a random component. First, a Monte Carlo simulation procedure is used to draw a sample value from the known crop yield distribution for each year of a 15-year planning period. This sample value represents the sum of base and random components. Then, using the series of yields, the model is solved for the 15-year period. Doing these two steps 20 times gives a distribution of outcomes based on yield variance. The model maximizes net worth (undiscounted accumulated wealth), and is recursive (interrelated between years) only on credit reserve.

Johnson points out that a major problem is in "choice between using probability distributions of raw data or using the best theoretical fit that can be obtained to the data. In the first case, all that one is doing is simulating the past (18, 19).

Boehlje-White model. A further development expands on the Martin-Johnson approach by reintroducing the enterprise choice question each year (3). It does not have stochastic elements, but does attempt to incorporate both annual production and investment into a single model, as illustrated conceptually in table 4.

Boehlje tried both net worth and disposable income objective functions. The former is illustrated here. Each of 10 time periods is described by four submatrices: (1) A production and annual input matrix, corresponding to the conventional monoperiod LP model. (2) An investment matrix, corresponding to investment theory. It makes increased capital stock available, converting financial assets to fixed facilities. It is related to production through durable input supplies, to credit through liquidity, credit, and net worth constraints, and to income division through net worth. (3) A credit matrix considering both long and intermediate term borrowing, principal repayment, and interest repayment activities. All short term funds are assumed to be borrowed at 7 percent. (4) A division-of-income matrix which apportions consumption and investment. The consumption plus taxes function has a constant plus a marginal withdrawal rate of 0.5. The reinvestment funds can be transferred to either intermediate or long term investment funds for future periods. The blocks of constraints for a particular year

Table 4.--Simplified two-period structure of the Boehlje-White linear programming model

Item	Production and annual input purchase	Investment	Credit	Division of income	Production and annual input purchase	Investment	Credit	Division of income	Net worth
Objective[1]..................				C				C	
Period 1 constraint sets: [2,3]									
Liquid capital............		A	A						
Credit....................		A	A						
Annual inputs.............	A								
Durable inputs............	A	A							
Income division...........	A			A					
Net worth.................		A	A	A					
Period 2 constraint sets: [2,3]									
Liquid capital............				A		A	A		
Credit....................		A	A			A	A		
Annual inputs.............					A				
Durable inputs............		A			A	A			
Income division...........					A			A	
Net worth.................		A				A	A	A	A

[1] This illustrative example is set up for optimizing on disposable income. To optimize on net worth, the C values indicated in the example would be replaced by zeroes, and a positive value would be entered in the objective for the net worth activity (which is evaluated at the end of the final period).

[2] Each row and each column represents a group of constraints or activities of the type indicated by the title. Details on the formulation of individual submatrices A are described in the source thesis.

[3] The income division row is an equality. The others carry greater-or-equal signs.

include categories for annual inputs, durable inputs, credit, liquidity, annual disposable income, and annual net worth. The latter two are tied to the objective function. Consecutive years are related through the effects of investment on (1) the supply of durables in later periods, (2) remaining capacity to borrow, and (3) the reinvestment capital transferred between periods.

It should be apparent that this sort of model lends itself to testing a wide variety of hypotheses. One hypothesis tested was that a simultaneous solution to a series of 10 years, each with a 79 x 49 matrix, exceeded available computer feasibility limits. After many false starts, this was disproved on an IBM 7094 with LP/90 when a feasible solution was reached after 4 hours, and successive optima required an additional 15 minutes from restart. To obtain even this speed, it was necessary to first solve the model with only the objective function for the first year, then add a second, and so on, using the disposable income criterion. A surprising result was that the solution for a year did not change as new year objectives were added and solved for. Apparently the simultaneity was not as strong as expected, at least in the backward direction.[8]

Other than for computing time, the results seem to describe a reasonable pattern of behavior over 10 years. Capital is gradually substituted for labor as the internally and externally generated funds are plowed into the business. The disposable income criterion tends to favor internal generation of funds, while the net worth criterion allows external generation. Additional work is possible, much in the same manner as already described for the original Loftsgard-Heady approach. The prime targets might include managerial ability and stochastic solutions. However, this model clearly points out a major frustration (viewed differently, a great potential benefit) in doing dynamic analysis--there are so many alternatives that one hardly knows where to start. One is literally forced to go to the real world for promising hypotheses to test.

RECURSIVE PROGRAMMING

A model that takes a different approach to describing the decision process of the farm firm and the attendant growth process is recursive linear programming. The LP model is for a single year, but it is solved a number of times in a sequence, with slight alterations each step. Restrictions for any given year depend on the optimum solution for the previous year. Flexibility constraints, consisting of upper and lower bounds on certain variables, are used to represent temporary limits placed upon the growth process by external factors.

The early applications by Richard Day (4), Schaller and Dean (32), and those developing the "FPED national model" (31) were based on a model for an area, and the growth concepts used were thus of an aggregate regional nature. Flexibility constraints consisted of restrictions on the rate at which profitable new technology became available, and on the rate at which labor would exit. On some external factors, both upper and lower limits were included.

A more recent published work by Theodor Heidhues (11) applies the same mathematical structure to the individual farm growth process. He then uses the model to examine some effects of possible EEC policies on different types of farms in northern Germany.

The model is set up as monoperiod programming models have been, except for three important features: (1) Detailed accumulative equations are provided to handle financial terms; (2) Investment and disinvestments, involving a fixed asset concept, are included in the model; (3) The model is related to another model for the following period by the fact that the P_0 values are functionally related to the optimum solution of the previous period. Solutions follow a sequential pattern, and the objective maximized is present value of returns.

Heidhues specifically considers two dynamic factors in farm adjustment: the environmental effect of technological and price variations, and the effect of a rising nonfarm standard of living on farmer income expectations. The basis

[8] A suggested improvement is to incorporate more objective function values directly, rather than putting them in an accumulating equation and then transferring the value to the objective via a single activity. Apparently the indirect imputation process requires many iterations and much cycling to make explicit the Z-C values only implied for each activity in the present structuring.

of the model is that adjustments come with a time lag. This reflects both quasi-fixed factor supply limits and uncertainty. Thus a learning period can be built in.

Investment-disinvestment follows the G. Johnson acquisition-salvage concept, with the modification that decisions are made on current expectation of annual income and cost (16).

The restrictions on the equations are of the following form:

$$\begin{bmatrix}\text{b value}\\ \text{for time}\\ \text{t}\end{bmatrix} = \begin{bmatrix}\text{Amount available}\\ \text{at beginning of}\\ \text{previous period}\end{bmatrix} - \begin{bmatrix}\text{Depreciation}\\ \text{if any}\\ \end{bmatrix}$$

$$+ \begin{bmatrix}\text{Amount added to}\\ \text{optimum solu-}\\ \text{tion of previous}\\ \text{period}\end{bmatrix} + \begin{bmatrix}\text{Exogenous}\\ \text{adjustment}\\ \\ \end{bmatrix}$$

Conceptually, this is very similar to the transfer equations already seen in the multiperiod models. The difference is that the Heidhues model solves one period at a time, sequentially. Thus choice between the two approaches depends on your conception of the decision process. Future expected returns are implicitly assumed to be constant for investments. The objective function maximizes ability of the farm to accumulate investment capital, subject to the consumption function and other requirements. Between successive years in the model, in addition to the changes in resource restriction, annual hired wage rate increases at the rate of 10 percent per year and consumption level increases to reflect a growing economy. Yields are increased according to projections from trends.

As illustrated in table 5, the model is tied together across production, labor hire, investment, fixed obligation, and money market sectors by a pair of equations controlling internal flow of funds. One insures that downpayments and total payment can be met, the other that annual commitments can be paid. The first category is of a one-time nature, while the latter is regularly recurring.

The time period of a single model was 3 years, and was run for each farm for 2 periods only. Matrix size each period ranged from 25 to 40 constraints and 40 to 60 activities.

As Heidhues asserts, "The ability to handle stocks and flows of money capital is a measure of the usefulness of a farm growth model" (16, p. 675). We will thus examine them in some detail. The requirements are that (1) certain annual fixed obligations, plus payment of principal and interest, must be met, (2) the remainder must be distributed between purchase of annual inputs, durables, and saving, and (3) liquidity must be maintained in terms of annual obligations. Some behavioral limits on borrowing must be observed.

Internal flow requires first a liquidity or flow-of-funds equation to insure that annual cash in-flow is adequate to meet current commitments. Second, an investment capital equation guarantees that long-term funds committed to new investment, to saving, and to additional liquidity requirements do not exceed those made available from disinvestments, borrowing, bank accounts, and surplus in the previous year's liquidity account. Current production returns are not available for current investment. Transfer of funds between years is made by accumulating in the liquidity equation and transferring to the P_0 values for investment funds the following year.

External flow includes three equations. The total debt limit equation is set by the balance sheet of the farmer, as a percentage of pledgable assets adjusted for previous commitments. In addition, the rate-of-borrowing equation can be set to insure that total debts do not increase beyond certain absolute limits. Finally, a repayment equation insures that commitments on both principal and interest are met.

Among the growth parameters that can be manipulated are depreciation or obsolescence of durables, rate of growth in either private consumption or the general wage rate, variations in externally determined fixed expenditures, and rate of increase in borrowing permitted. Others could be incorporated--as illustrated by some of the models discussed earlier. In addition, it would be possible to include some pairs of lower bound-upper bound behavioral restrictions on the individual, as are found in the aggregate applications of recursive programming. These might express inability to

Table 5.--Simplified structure of the Heidhues individual firm recursive programming model

Item	Production, annual purchase and sale	Labor hire	Investment and disinvestment	Fixed obligations	Borrow and repay (money sector)
Land Crop Seed Livestock Labor	A_{11}	A_{12}	0	0	0
Technical equipment Machinery Buildings	A_{21}	0	A_{23}	0	0
Consumption Fixed charges	0	0	0	A_{34}	0
Capital: Internal flow: Liquidity Investment	A_{41}	A_{42}	A_{43}	A_{44}	A_{45}
External flow: Debt limit Borrowing rate Repayment	0	0	0	0	A_{55}

Details on internal flow of capital:

Liquidity: Hired labor expense + Fixed obligation $\leqq$ Production return + Interest income + Transfer from investment capital

Investment: Investment commitment + Transfer to liquidity account = Disinvestment + Borrowing + Bank account + Surplus liquidity of previous period

Details on external capital equations:

Total debt: Borrowing $\leq$ Previous years debt limit + Loans paid off in previous period - Previous period new borrowing

Rate of borrowing: Borrowing rate = α(Previous limit) + Previous repayment - Increase in previous period

Repayment: Repayment = Fraction of last period borrowing due + Fraction of repayment due from commitment of earlier periods

Source: (11).

312-914 O-68—3

make very large changes in individual enterprises over the short run.

SIMULATION MODELS

Still another approach to handling firm behavior over time is found in simulation models. In a broad sense, all the models attempt to simulate behavior of a farm firm over time. But one definition confines the term to models which are not strictly optimizing--do not have an analytic optimizing procedure--however close the approximation procedure may come. Of course, even optimizing may be severely constrained by all sorts of side restrictions, but the distinction used here is whether or not the criterion is maximized via an analytic mathematical technique. Eisgruber [9] and Hutton (13) both make the distinction that simulation models are nonanalytic (that is, they do not guarantee an optimum), and if analytic-optimizing models can handle the situation they are to be preferred. Thus the simulation models have their place when the decision process to be described is extremely complex, and analytic approaches either have not been or cannot be developed. These include situations with (1) multiple goals, (2) indivisibilities, (3) sequential decisions within the planning period, using different criteria, (4) nonlinear functions, and (5) concepts of organizational, managerial, and behavioral theories (8, 12).

Simulator decision models are ordinarily written in some computer user's language. They tend to call for less abstraction than the analytic models, so that it is a much more difficult question to decide how far to go on details of the decision process being modeled. Because of the sequential nature of the models and a growing computer inventory, the computer time restriction is simply much less pressing than for an LP problem of the same size--though with extremely large problems the core memory capacity may be taxed (7).

Once the computer program describing the desired decision process has been produced, we may think of its use in evaluating a policy as a sequence of experiments (27, ch. 9). Though the procedure does not guarantee an optimum and may not even seek one, research procedures may include the requirement that several alternatives be generated and the best of these chosen. The experimental aspect gets introduced by varying some independent or policy variables and evaluating the effect on outcome from the model. Another type of use of these models is to describe a particular decision process to allow tracing through effects of different inputs. Here the primary interest is in an algorithm to simplify computational burdens.

With so much flexibility available, the range of alternatives is as broad as the set of decision models one can specify and quantify. Because of this flexibility, the simulator has found use in research efforts designed to try to study the growth process of the individual firm. These studies may require a more detailed decision model than do more aggregate representative firm or supply studies--a model bringing in concepts of managerial, behavioral, and decision theory. These models lend themselves to progressive development, as is apparent in the following paragraphs. Because of their nature, the discussion that follows is necessarily more conceptual and abstract than that of the optimizing models.

To illustrate, we turn briefly to the general structure of a series of related models developed at Purdue University. Eisgruber initially wrote a program to simulate a farm operation (1, 6). Alternatively it could be used in management games as a classroom device. It was strictly an operating model, built around analyzing the effects of yearly plans and of land purchase decisions. The decision procedure followed the general land use planning approach. Input variables required for each year included acreage of each crop, fertilization levels, livestock number and types, and decision on land purchase. An option for stochastic yield and price coefficients was provided.

Subsequently, George Patrick (28) built a model simulating the entire farm business. His annual farm operation submodel was developed from Eisgruber's model, dropping the stochastic variable generator. The Patrick

[9] L. M. Eisgruber, Seminar on Simulation, unpublished notes, Purdue University, Department of Agricultural Economics, April 1967.

model draws extensively from behavioral concepts advanced by Simon and others, and uses four goals of the family, expectations on prices, and a consumption function related to family size and income level.[10]

Figure 1 shows a simplified version of the decision process used by Patrick. Figure 2 is a detailed breakdown of the planning process involved in the lower left quadrant of figure 1. Parameters studied in the model are the starting farm resource situation, plus a specification of which of three alternative levels to use for each of the following controlled (studied) variables: (1) managerial ability, (2) interest rate, (3) long-term loan limit, and (4) intermediate-term loan limit. Combinations of the variables were simulated for the farm over a 20-year period. The model itself incorporates many of the features discussed in the first paragraph of this section.

Edward Harshbarger has reintroduced stochastic yield and price variations to the model, has added land purchase and machinery enlargement, and has developed certain other modifications.[11] The variables he is studying include four land procurement policies, different equity ratio limits on borrowing, and different long and intermediate term loan limits. Land strategies range from buying at every opportunity to rental only. Liberal and conservative borrowing policies of 80 and 40 percent are considered. A third project, sponsored jointly by Economic Research Service and Purdue University, will probably build in additional detail in the direction of financial leverage and more sophistication in the area of income taxation and tax policy.[12] [13]

[10] See Patrick (28) for additional diagrams and details of the decision process assumed in the model.

[11] These results are to be reported in a Ph.D. thesis in preparation: C. E. Harshbarger, The effect of alternative strategies used in decision making on firm growth and adjustment (Purdue University).

[12] Virden Harrison (ERS), under the direction of W. H. M. Morris and George D. Irwin, is the project investigator.

[13] For a simulator including farm corporation tax policy, see N. E. Harl (10).

Research Strategy

Logic dictates the sequence-of-projects approach to programming and simulation, rather than so many "one shot" efforts. Any type of model building is expensive work, but the marginal cost of expanding a relatively satisfactory model is small. Further, several studies are required to realize the potential of a new model. A criticism of most growth studies to date, including both programming and simulation, is that they utilize the models so little for analyses after going to so much trouble to build them. This, of course, is partly a reflection of the dominance of dissertation work in the total agricultural economics research program. In addition, a group of roughly comparable studies offer the possibilities of comparative analyses.

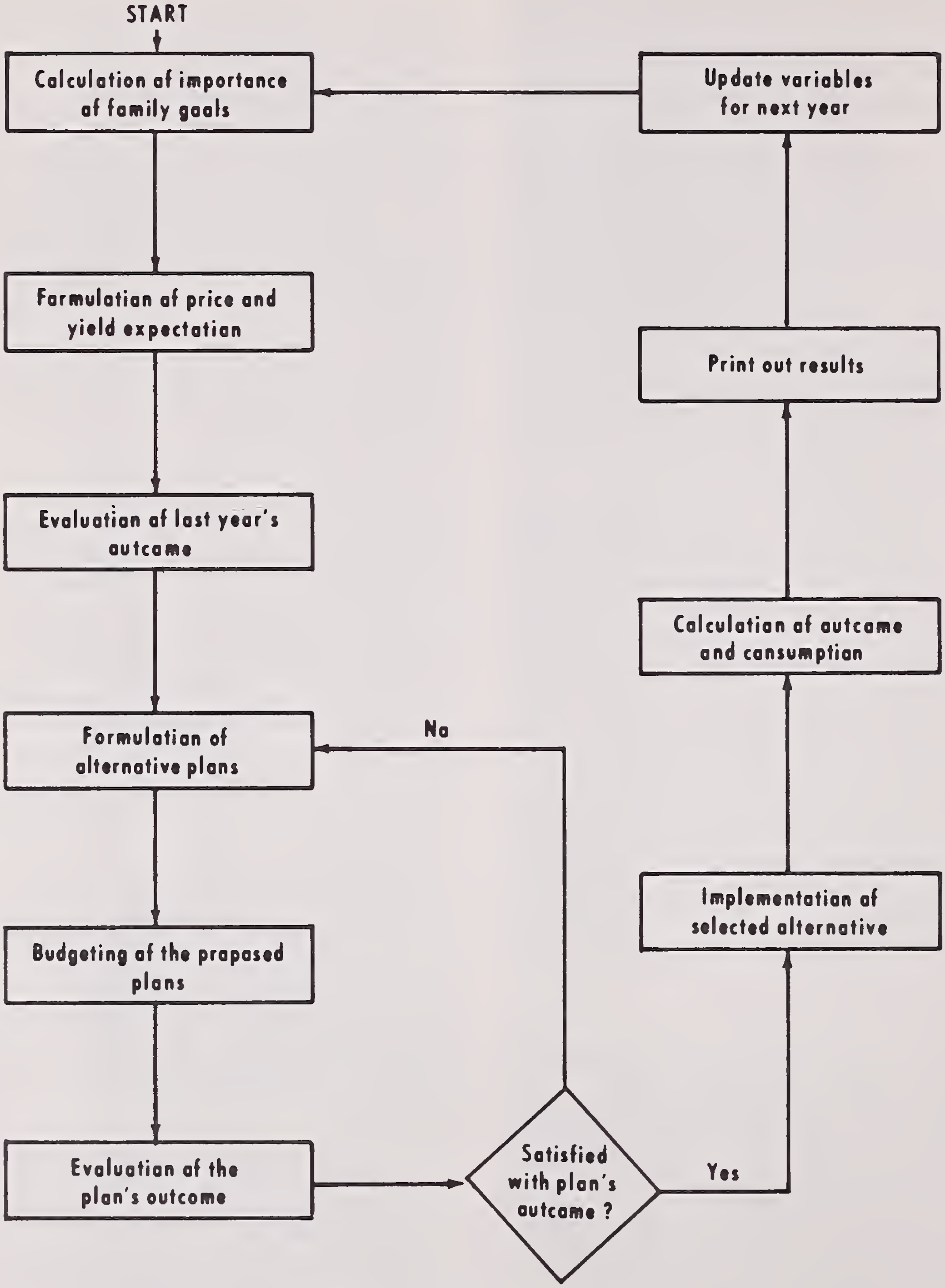
Markov chain analysis may offer an approach to changes in the aggregate size distribution of firms to which the more micro oriented studies could be related.[14] [15] Further developments may also want to take advantage of the new model structures of quadratic and dynamic programming, which imply potentially useful new dimensions of the decision process. Each of these emphasizes once again that introducing growth features into models strains our data banks. Clearly, also, a high priority needs to be placed on research into understanding the decision process we are now able to model more completely.

One important question which needs to be investigated in the near future is the correspondence of the behavior of the model to real world behavior, the question of validation. We need to ask whether the decision process incorporated is able to simulate farmer behavior. Unhappily, the more complex the model, the more difficult it is to validate. Masking of effects is an ever present pitfall to analysts.

[14] Lee Day suggested to the author that this approach might allow one to bring extra-firm characteristics into a firm growth study.

[15] John H. Berry, FPED, ERS-Purdue University has used Markov chains to project the changing size distribution of firms for an aggregate supply study, based on a representative firm approach.

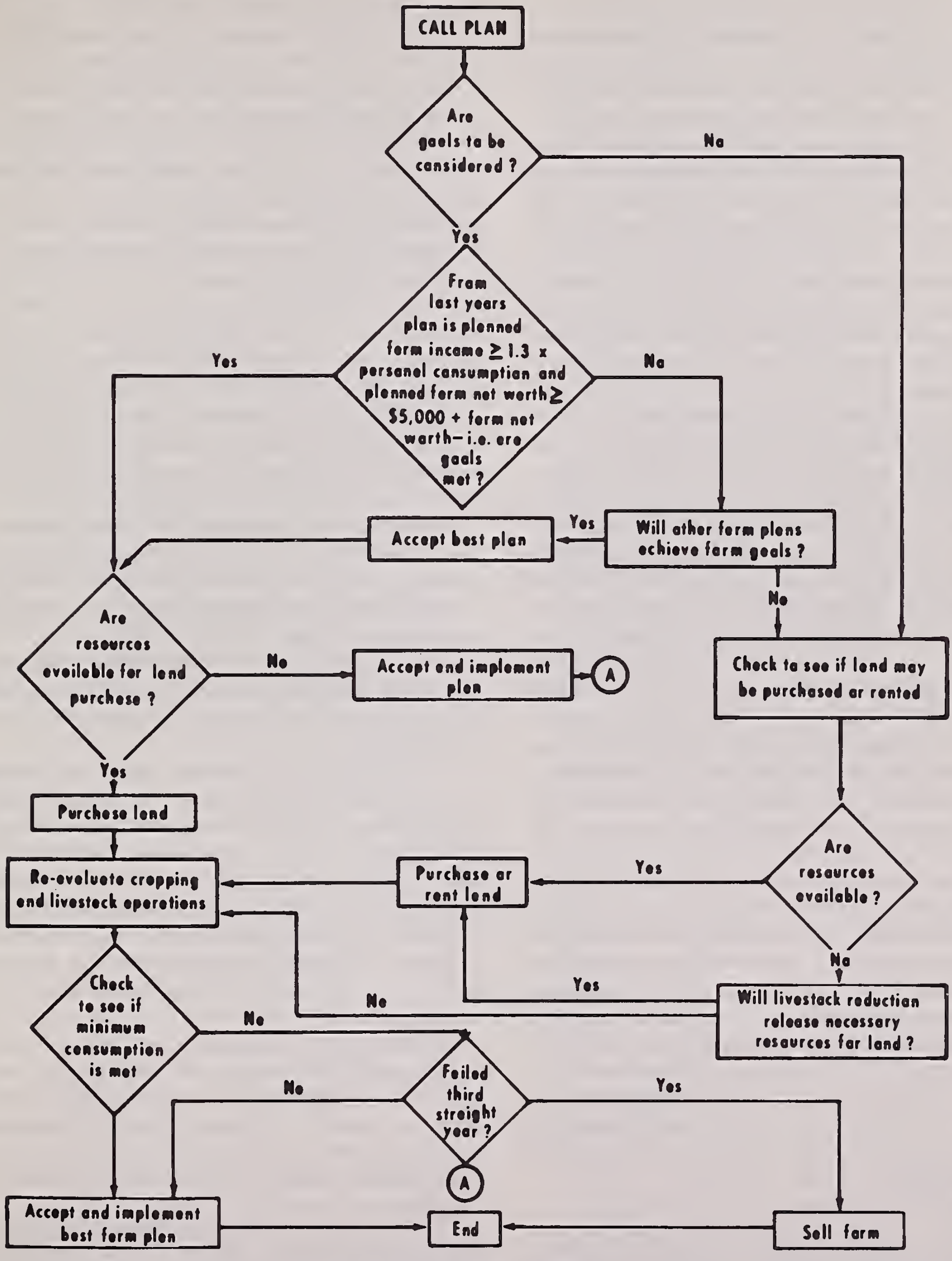
SCHEMATIC DIAGRAM OF PATRICK'S SIMULATOR



SOURCE: G.F. PATRICK (28)

Figure 1

SCHEMATIC DIAGRAM OF PLANNING PROCESS IN PATRICK'S SIMULATOR



SOURCE: G.F. PATRICK (28)

Figure 2

In Summary

After a brief review of growth principles and comparative static approaches, we have looked at three kinds of models, which differ basically in their conceptualization of the decision process. The recursive programming and simulation models make sequential decisions, with a certain amount of the future involved, depending on how the price expectations are formulated. On the other hand, the multiperiod programming approach explicitly makes a simultaneous solution for all future periods, given present information. Whatever the decision process chosen, detailing the internal and external flow of funds is at the core of the growth process.

The two programming approaches are optimizing while simulation is not.[16] This raises an interesting empiric problem. Many LP solutions seem to show relatively flat profit surfaces near the optimum. This means that enterprise combinations can change substantially with only small effects on profits. Thus chances are good that simulation may yield nearly the same profit as an optimizing model; but the enterprise combination may be quite different. In the aggregate, the question is crucial. On the other hand, a flat profit surface means that there is little opportunity cost in considering some farmer preferences--so they could well belong as constraints on the activity set considered in our LP models.

Each of the approaches has possibilities for embodying various decision models, with simulation being the most flexible. The crucial aspects of fund flows and of combining annual production and investment equations have been demonstrated for each. In sum, we probably need more work with each before deciding which is the appropriate decision model. Even then, it would be no surprise if the answer turns out to be conditional--depending on the type of problem being studied.

Finally, let us close with a few suggestions on placing these models in larger perspective for evaluating research proposals:

1. It would be possible to have a multiperiod model in which the later period plans were considered only tentative. The first-year plan could be adopted; then the data could be updated, the first year dropped, a later year added, and the model rerun. This would make the multiperiod model sequential. In fact, the later periods could be combinations of years, to approximate a decreasing consideration of an increasingly distant future.

2. Quite apart from growth models, the idea of potential growth could be used to classify representative farms. Most farms cannot be expected to grow and some must necessarily decay (2, 26). A growth model, or at least a growth study, should perhaps be able to handle both investment and disinvestment, particularly if we have any interest in aggregates.

3. It may be appropriate in all models to limit the range of alternatives available to the farmer, increasing them with experience, decreasing them with fixed attitudes, or classifying them by type of farm. Using this for the NC-54 study in Indiana (described in 9) we got markedly different results from those obtained when all alternatives were considered for all farm types.

4. There may be some merit in breaking our traditional enterprise classifications up functionally. Just as enterprise specialization developed on farms, one might anticipate further specialization functionally by operating, financing, etc. (29).[17] Identifying growth sectors in this way may give a much more precise method of studying changes in an industry. Robinson (30) refers to this as process concentration.

5. Much of the work involved in growth studies probably should be supporting, rather than on models per se. "Garbage in--garbage out" is clearly a growing problem as models become more comprehensive. In particular, consumption functions and tax rates are critical.

[16] One recent study combines the approaches, using a linear programming model as a subroutine in a simulator, to handle annual optimizing. See Harl (10).

[17] At the 1967 American Farm Economics Association session on firm growth, Warren Bailey presented a similar analysis for a crop enterprise, breaking the functions into operating, ownership control, and investment.

Note that the studies reviewed here had marginal propensities to consume varying from 0 to 0.5 and none considered social security tax at all. Unfortunately, a corresponding characteristic of more complex models is that these assumptions become easier to conceal.

6, There needs to be more followthrough analysis after heavy investment is made in construction of a model.

7. Growth models require more detailed tie-in with the larger, macro environment than static models, with allowance for feedback if all farms in a region do the same thing at the same time.

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An Economic Model of Vertical Integration and Multiple Pricing Based on the Maple Sirup Industry[1]

By Reed D. Taylor and Jerome K. Pasto

THE ECONOMIC MODEL presented in this paper is based on empirical data collected on the maple sirup industry. It illustrates the competitive position of agricultural producers who sell consumer products at different levels of the production, processing, and marketing chain. The data were obtained by a mail questionnaire sent to all known maple sirup producers in the United States. Seventy percent of the producers responded to the questionnaire.

The maple sirup industry has five claims to distinction: (1) it is one of the oldest American agricultural industries, having been practiced by the early Indians; (2) world production is confined almost entirely to the North American continent; (3) it has a very high degree of vertical integration; (4) it is the only agricultural industry wherein palatable products are produced from the sap of a tree; and (5) it is one of the few agricultural commodities produced in the United States of which imports normally exceed domestic production.

Production of maple sirup is confined to natural growth areas of hard maple trees. This restricts production in the United States primarily to the Great Lakes area and the Northeast, and in Canada to the Eastern Provinces of Nova Scotia, New Brunswick, Quebec, and Ontario. Of the normal world annual production of 3 million gallons of sirup, Canada usually produces two-thirds and the United States one-third. Consumption is reversed, with the United States consuming approximately two-thirds and Canada one-third.

[1] This article represents part of a research project that was cosponsored by the Pennsylvania State University and the Marketing Economics Division, ERS. The entire study is described in a Ph.D. dissertation by Reed D. Taylor entitled "Characteristics of the United States Producer Maple Syrup Markets."

In the United States hard maple groves are scattered, usually being found in hilly regions at least 400 feet above sea level. Since sap is converted to sirup within a short distance of where the sap is collected, production facilities also are widely scattered.

About 87 percent of the U.S. producers are either full-time or part-time farmers, with sirup production making up an average of 23 percent of their total farm gross receipts. Traditionally, individual producers have boiled the approximately 40 gallons of sap required to produce 1 gallon of sirup. The product is "consumer finished," with the exception of packaging. Most producers also package the sirup for consumers.

Maple Sirup Sales

Multiple pricing is practiced by maple sirup producers in the United States. Products of equal quality are sold in alternative markets at price differentials that exceed differences in market costs.

Sirup is graded in four categories: Fancy, A, B, and C. Fancy and A are considered table grade, while B and C usually are sold for manufacturing purposes. About 77 percent of U.S. production is table grade, and 23 percent is manufacturing grade (table 1). Since table grade is the only sirup which has alternative markets, it alone is included in the analysis of producer marketing behavior.

Table grade sirup is sold by producers directly to consumers, retailers, and manufactures. Difference in packaging is the only modification required in processing for these alternative markets. Sirup sold to manufacturers is packaged in drums; the rest is in consumer packages.

Table 1.--Distribution of maple sirup produced by grade, 1,493 producers in 14 States, 1963

Grade	Percent of production
Fancy	45
A	32
B	16
C	7
Total	100

Source: (4, table 55).

Eighty-eight percent of producers sold table grade sirup directly to consumers, disposing of 60 percent of their output at a weighted average price of $6.22 per gallon equivalent, (table 2). A high percentage of these sales were to tourists. Twenty-one percent sold to retailers, disposing of 16 percent at an average price of $5.91 per gallon. Thirty-three percent sold to manufacturers, moving 24 percent of the product at an average price of $3.55 per gallon. Sirup sold directly to consumers grossed almost twice as much per gallon as that sold to manufacturers.

Producers differentiate and sell simultaneously in the different markets by the use of multiple pricing. In addition, the individual producer grows his own trees, collects sap from them, manufactures sirup, and packages it in consumer packages. The maple sirup industry probably represents the highest degree of producer vertical integration in agriculture.

Plant Budgets

Budgeting of maple sirup operations suggested that producers acted rationally in their marketing decisions. Budgets, including all processing and marketing costs, revealed significant differences in operator returns (profit, labor, and management) among the three markets. In the smallest plant budgeted, with annual capacity of 7,292 gallons of sirup, operator returns were $1.32 per gallon when all table grade sirup was sold to consumers, $0.97 when all was sold to retailers, and $0.34 when sold to manufacturers (4, tables 81-92).[2]

Effects of Size on Producer Behavior

Size of operation is an important factor in influencing market behavior. Maple sirup producers were divided into five categories based on total gallons produced. Categories selected were 0-199, 200-399, 400-599, 600-799, and 800 gallons and over. Since trends were the same in all five cases, size categories 200-399

[2] Underscored numbers in parentheses refer to items in the References, p. 106.

Table 2.--Distribution of table grade maple syrup and prices received by market, 1,493 producers in 14 States, 1963

Market	Percent of producers[a]	Percent of production	Price per gallon equivalent
Direct sales to consumers	88	60	$6.22
Sales to retail outlets	21	16	5.91
Sales to manufacturers	33	24	3.55
Total or average	--	100	$5.53

[a] Since some producers sold products in more than one market, the percentages add to more than 100.

Source: (4, tables 17, 18, 41, 42, 62).

and 600-799 were omitted to simplify presentation. In this paper the smallest category refers to producers of 0-199 gallons, and the largest refers to those producing 800 gallons and over.

Size of operation proved to be a significant factor in explaining market distribution by individual producers (table 3). Seventy percent of the smallest producers sold to consumers exclusively. Most of the largest producers sold in more than one market; large producers found the direct consumer market profitable but limited. In sales to retailers, however, small size was a limiting factor since retailers need substantial sirup supplies on a reliable basis. Only 13 percent of the smallest producers sold to retailers (1 percent sold to retailers exclusively), while almost half of the largest producers sold to retailers. Sales to manufacturers were made by more than half of the largest producers but only 19 percent of the smallest.

Nearly all producers sold to the more profitable markets--consumers and retailers. Sales to manufacturers were made primarily to dispose of "surplus" table grade sirup.

The larger the producer, the more difficult it is for him to market his entire supply directly to consumers, although 14 firms did it. Most sales directly to consumers take place on the farm. This limits the potential number of customers for most producers. A producer's optimal strategy is to sell to different markets at prices determined by supply and demand.

Most individual maple sirup producers meet the three conditions necessary for successful multiple pricing. First, they have three separate markets. They can package and retail sirup on the farm at a lower cost per unit than can be

Table 3.--Percentage of producers selling table grade maple sirup by outlet and size of operation, 1,493 producers in 14 States, 1963

Sales outlet	Average for all sizes	Size of operation in total gallons per producer[a]		
		0-199	400-599	800 and over
Individual outlets:	Percent	Percent	Percent	Percent
Consumers	[b](88)	(92)	(83)	(89)
Consumers exclusively	52	70	30	19
Retailers	(21)	(13)	(31)	(47)
Retailers exclusively	2	1	2	0
Manufacturers	(33)	(19)	(50)	(55)
Manufacturers exclusively	9	6	15	10
Multiple outlets:				
Consumers and retailers	13	10	18	26
Consumers and manufacturers	18	11	24	24
Retailers and manufacturers	1	1	0	1
Consumers, retailers, and manufacturers	5	1	11	20
Total	100	100	100	100
Number of producers in size category	1,472	704	169	74

[a] For simplification, size categories 200-399 and 600-799 were omitted. Data for these categories showed the same trends as for the ones included. The complete table is in (4, table 62).

[b] Percentages in parentheses represent producers who sold in more than one market, and therefore they add to more than 100.

done through usual marketing channels. Second, elasticities of demand at each price level differ between markets. Third, producers have market power in selling to consumers and retailers. In consumer sales, the market structure on the producer's side varies between monopolistic competition and monopoly but approaches pure competition for the consumer. In sales to retailers, the producer's side can best be described as ranging between pure and differentiated oligopoly, while the retailer's would vary between pure and differentiated oligopsony. In selling to manufacturers, structure is best described as pure competition for the producer and pure oligopsony for the manufacturer (4, chapters III, V, and VI).

Because the smaller producers find it difficult to sell to retailers, they are in a somewhat weaker position than that of pure of differentiated oligopoly ascribed to larger maple sirup producers selling to retailers.

Model of Market Behavior

The following describes the competitive situation facing individual agricultural producers who sell consumer products at different levels of the production, processing, and marketing chain. Although based on the maple sirup industry, we believe the description applies to other agricultural industries. Where vertical integration is practiced and consumer products are produced, the opportunity for multiple pricing is present even if not exercised.

Each of the three markets in the maple sirup industry presents a different demand curve to the individual producer (fig. 1).

The direct consumer market (packaged) has the most inelastic demand curve. The packaged wholesale market is more elastic than the direct market to consumers but more inelastic than the wholesale drum market to manufacturers. The latter market has an almost perfectly elastic demand curve and approaches perfect competition. Demand curves for sirup are considered net of marketing costs. To maximize returns with any given quantity, a producer should distribute his sales in such a way that marginal revenue in each market is equal to marginal revenue in other markets. Vertical integration allows the producer to sell in different markets. Structural characteristics of these markets permit him to optimize his profit stream by multiple pricing.

Assume that a producer sells in the three markets, as in figure 2. The demand curve for retailing direct to consumers is D_1D_1, for selling packaged sirup to wholesalers D_2D_2, and for selling drum (unpackaged) sirup to manufacturers D_3D_3. The respective marginal revenue curves are MR_1MR_1, MR_2MR_2, and MR_3MR_3. The sum of the marginal revenue curves is shown by the curve ABCD. To maximize total returns with any given output the producer should sell his entire output (quantity) directly to consumers if it is equal to or less than point B; divide his sales between consumers and retailers when output is more than B but equal to or less than C; and use all three markets if output is greater than C. If output is greater than C, there will be a unique distribution of product in the three markets. For example, if the output were C or more, the quantity OQ_1 always would be sold to consumers at a price P_1;

Figure 1.--Relative configurations of demand curves facing individual maple sirup producers.

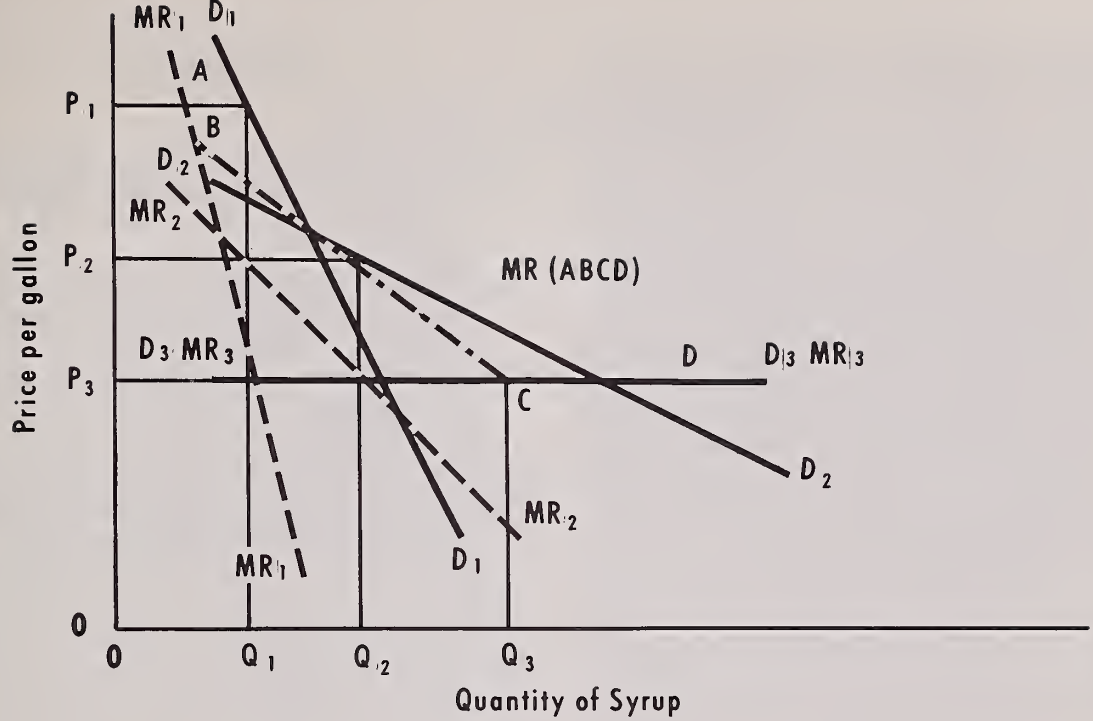

Figure 2.--Aggregate configurations of demand curves facing individual maple sirup producers.

the quantity OQ_2 would be sold to retailers at a price P_2; and any remainder would be sold to manufacturers at a price P_3.

One difference exists between the type of behavior explained in the model presented herein and the theoretical model of multiple pricing presented in the literature (2,3). The usual model of multiple pricing describes income maximizing behavior of a monopolist selling an identical product in two or more separate markets at one horizontal level of the production, processing, and marketing chain. Our model for individual maple sirup producers and other similar industries resembles the one proposed by researchers for the milk market where multiple pricing occurs as a result of selling the same quality product at different prices at different vertical levels of the production, processing, and marketing chain (1). Although multiple pricing in the milk market results primarily from extensive State and Federal market controls and other insitututional regulations, it occurs in the maple sirup industry at the individual producer level of marketing because of vertical integration and inherent structural characteristics of the market.

Implications

Examples of producers whose competitive situation is similar to that of maple sirup producers are: (1) Large egg producers who have retail and wholesale routes but who sell the bulk of their eggs to large wholesale buyers, either whole, or processed into dried or frozen form; (2) milk producers who have "call-at-the farm" jug sales, retail routes, and wholesale outlets; (3) greenhouse operators who retail direct to consumers, sell wholesale to retail outlets, and offer their product to wholesalers; (4) fruit, vegetable, and nut growers who sell from roadside stands or the farm, who sell to retail outlets, and who wholesale to processors or through brokers; (5) and the many integrated operations (broilers, layers, turkeys, swine, beef) in which the integrator has access to several vertical markets and thereby the opportunity to use multiple pricing.

Maple sirup producers and other agricultural producers fitting the suggested model would have market power in some markets. The closer the producers sell to the consumer, the greater their power. Agricultural producers selling

some types of products might well be in the position of monopolistic competition or pure or differentiated oligopoly, rather than the postion of pure competition usually attributed to them by economic theorists. Further studies of the type reported here would be highly useful in determining present and potential competitive behavior in agricultural producers' markets.

Realistic economic models can be highly useful in determining market strategy and also in providing a basis for useful policy proposals. The model presented herein, as an example, shows profit maximizing potential by producers of certain products, based on market power inherent within the industry, in the absence of Government regulation and control.

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Book Reviews

Intermediate Economic Statistics

By Karl A. Fox. John Wiley and Sons, Inc., New York. 568 pages. 1968. $13.50.

WITH THE PUBLICATION of this text, Karl Fox hopes to update economic training--undergraduate as well as graduate. According to Fox, "dramatic changes have been accumulating since the mid-1930's." These changes are highlighted as he sets out to integrate statistical techniques with the concepts and problems of economics. To help him reach this objective he has at his disposal a wealth of experience gained from his work in and outside Government agencies.

In the opinion of this reviewer, however, the text serves a different role. Placed in the hands of the experienced instructor or the seasoned analyst, it makes available the practical insights of a knowledgeable economist and researcher. It serves as a valuable supplement to standard reference materials. Since it relies on recent developments in economic analysis, the practicing analyst and the novice can benefit from this author's experience.

Fox states that his first nine chapters could be used as the basis for an undergraduate course; chapters 5 through 14, the basis for a graduate level course. The text begins with a presentation of background material on the role of economics and then proceeds to review economic and statistical concepts in two brief chapters. Fox notes that the student should have covered the content of an "adequate" economic principles course as well as a statistics course prior to these chapters. Thus, he plunges forward immediately. The logic of simple regression, a discussion of index numbers and time series, the interpretation of results from simple and multiple regression analysis, elements of analysis of variance, and structural analysis of economic time series are topics that take the reader through the first nine chapters.

The remainder of the book takes up the development of macroeconomic models. Two attempts at the construction of large-scale economic models of the U.S. economy, the Klein-Goldberger and the Brookings-SSRC econometric models, are described, together with a discussion of their relative merits and shortcomings. Fox recognizes the importance of such problems as multicollinearity, identification, and aggregation that are inherent in large-scale model building. Subsequent chapters go into these and other problems in more detail. In addition, alternative methods of estimation that have arisen in recent years are reviewed briefly by two colleagues, J. K. Sengupta and B. C. Sanyal.

Throughout the text, Fox makes liberal use of practical examples and charts in an attempt to illustrate certain relationships or to clarify a point. A times, more detailed formulations and further explanation are presented in an appendix to a chapter. The derivation of normal equations, matrix algebra fundamentals, and a short-cut graphic method of multiple regression are some topics shown this way. Exercises at the end of each chapter help to reemphasize important concepts for the student.

Fox does not treat theory and related mathematics fully in all cases. This may prove disappointing to some readers. The depth of detailed discussion varies depending on the topic. Consequently, his initial assumption of "adequate" preparation may be too rigid; perhaps, unrealistic. However, the important basic concepts are adequately referenced for the serious student who wishes to "dig a little deeper." For these reasons, I believe the text will be more useful at the graduate level. Most certainly, it is a worthwhile supplement for the practitioner.

Hyman Weingarten

Older Rural Americans–
A Sociological Perspective

Edited by E. Grant Youmans. University of Kentucky Press, Lexington. 321 pages. 1967. $8.75.

ALTHOUGH MOST OF THE chapters in this book are written by sociologists, there is much of interest for economists who may seek insights in interpreting their research findings, who may wish to include elements of sociology in future studies, or who may desire to evaluate priorities for research on problems of the rural aged.

Economists may be most interested in the chapters by Henry D. Sheldon, "Distribution of the Rural Aged Population," and Juanita M. Kreps, "Economic Status of the Rural Aged." The first of these chapters presents population comparisons for rural and urban aged with projections for future age relationships on a national level; the second contains analyses of employment opportunities for rural compared with urban aged.

The findings presented in most of the chapters are derived from case studies or from limited samples and hence do not lend themselves to widespread and unequivocal application. They do, however, suggest important questions or relationships for economists to consider. For example, the chapter on "The Middle-Aged and Older Rural Person and His Family" presents an explanation of the life cycle concept used as an independent variable and as a process. This concept could prove useful for analyzing consumption patterns of aged persons in household of various age-size compositions.

It is important to remember, as Arnold Rose pointed out in his essay on "The Rural Setting," that in studying the rural aged of today, one is attempting to prepare for needs of the rural aged of tomorrow. The rural community of today may be quite different from that which develops in the future--due both to changing rural-urban relationships and to the generational differences that will have been experienced by the aged of tomorrow.

Three chapters on minority groups indicate the special economic, social, and psychological problems associated with each. The American Indian, for example, characteristically does not manifest the appearance of old age until late in years. For this group, the difference between age as an idea and as a physiological actuality is important. Spanish-speaking Americans in the younger generations are becoming rapidly assimilated into the dominant culture. Hence, it is expected that in future generations of aged persons, illiteracy will be reduced and the minority group problems for Spanish Americans will become minimal or will disappear. Aged, rural Negroes have a very low socioeconomic status.

Other chapters deal with housing, health care, and community and work roles of the rural aged. One chapter describes Federal, State, and local programs for the aged. Examples are presented of specific projects in various areas of the country. Throughout the book, comparisons are made between rural and urban groups so that the relative position of the rural aged in society can be more clearly evaluated.

The book is written clearly and with a minimum of sociological terminology. The concepts and terms used are, for the most part, defined or presented so that a nonsociologist can understand the basic relationships.

Anne E. Hammill

Trade, Aid and Development–
the Rich and Poor Nations

By John Pincus. McGraw-Hill for the Council on Foreign Relations, New York and London. 400 pages. 1967. $10.

IN THIS INTERESTING, informative, and provocative book, Pincus attempts to bring together the various elements of international economic policy as they bear on the economic development of underdeveloped countries. The research and writing of this book were sponsored by The Council on Foreign Relations. The author has not tried to cover all aspects of development thoroughly in a single volume, since one of the major elements, international monetary arrangements, is discussed elsewhere. A second element, the effects of the domestic economic policies of poor countries on their trade, capital flows, and growth, is omitted because of limitations of time and space. The first two chapters present in general terms the political and economic bases for foreign aid and trade.

Next, there are two chapters which, as the author admits, digress from the main theme. These chapters review classical, neoclassical, and contemporary trade and development theory.

Three chapters (5 to 7) deal broadly with the principal policy issues of trade and development, embracing choices and issues of commercial trade policy for manufactured products and commodity trade.

Chapter 8 examines the demand for capital in the developed and the less developed countries (LDC's) in terms of the requirements, levels, forms, and sources of aid and the role of foreign private investment.

A summary chapter entitled "Policy for the Rich Nations" reviews the costs and benefits of foreign aid and surveys the limitations and prospects of trade, aid, and investment policies.

Pincus argues that each country which offers aid or other concessions does so in the expectation of receiving benefits. Testimony to this, he claims, is evidenced by the widespread doubts and continuing controversies about the merits of aid in the major donor countries.

Pincus states that aid and trade may substitute for each other to a limited extent and may also act to reinforce or offset each other's effects. Assuming that rich countries want to help poor ones but are reluctant to raise aid levels, he suggests that the rich should seek to promote trade and the poor to promote both aid and trade.

The United Nations Conference on Trade and Development (UNCTAD), which met in Geneva from March to June 1964, gave clear expression to three different conceptions of the international economy in addition to the Soviet view. The author indicates that in contrast to the advanced countries (excluding the USSR), which were reasonably content with their present level and share of the world's income, the less developed countries were profoundly dissatisfied with the present distribution of world income.

The author belabors the United States for what he regards as an excessively rigorous verbal devotion to liberal trade principles that it violates daily, and for failing to propose positive measures beyond those expected from what he regards as the long-oversold GATT negotiations. He asserts that basically the United States has never decided what it wants to gain from its aid to underdeveloped countries, although U.S. aid policy has stressed helping LDC's toward self-sufficiency.

Pincus believes that trade and investment promote a market discipline that stimulates growth, while aid may not. Trade, by enriching both parties, simultaneously makes it easier for the rich to give aid and less necessary for the poor to obtain it as a condition of growth. He indicates that there is clearly no special relation between trade and economic development. The percentage growth of Atlantic Community exports was nearly twice as great as its income growth during the past decade; underdeveloped countries' exports rose a little slower than income. Yet income in the two areas grew at nearly the same rate. These findings, he emphasizes, underline the possible error inherent in always equating income growth and trade growth. Even though some countries (Israel, Jordan, and Taiwan) have received an important stimulus from foreign aid, the mixed record of achievement reveals the inability of any single formula to explain economic growth, or its absence, in the LDC's. Each underdeveloped country is a special case, and each will develop differently.

Pincus' approach will be welcomed by all those who feel that a policy is impractical when it calls upon rich nations to give more aid and at the same time to renounce the exercise of political power. For truly effective economic aid, he calls for enlightened self-awareness on both sides: a clear understanding by the donor nation of what it can hope to achieve through economic concessions, what it will receive in return, and a clear knowledge on the part of the recipient nation of what is expected of it and what "strings" are attached to the trade or aid concessions received.

Robert L. Tontz and Isaac E. Lemon

Why Growth Rates Differ: Postwar Experience in Nine Western Countries

By Edward F. Denison assisted by Jean-Paul Poullier. The Brookings Institution, Washington, D.C. 492 pages. 1966. $12.50 cloth, $4.95 paper.

IN RECENT YEARS, many questions have been asked about economic growth--about its stages, its strategy, and its statistics. Edward Denison, in collaboration with Jean-Paul

Poullier, has done more than merely examine these questions; he has attempted to present some of the answers. He focuses on historical reality as it is related in the statistical records of economic change from 1950 to 1962 in nine Western nations: the United States, France, Germany, the United Kingdom, Italy, Norway, Belgium, the Netherlands, and Denmark. From this perspective he identifies 23 quantitative changes in inputs and efficiency which affect the dynamics of economic outputs.

The book is a straightforward statement. Denison identifies the assumptions from which he begins and presents data in support of the conclusions with which he ends. In between he convincingly demonstrates that economic growth is no easy process. The sources of growth are many and varied. Substantial increases in a nation's growth rate can be achieved only through a combined contribution from many sources. Small changes in growth rate result from relatively large changes in a single input.

Fortunately, Denison has not matched the complications of the process in his presentation. Instead, the ease and clarity of his writing seem to place the understanding of economic growth within the scope of human ability.

Among the many questions asked about economic growth are those questions which compare one nation's growth with another's. The concept of an economic gap is often misused. In the 1960 Presidential Campaign, John F. Kennedy stated that the U.S. growth rate was lowest among industrialized nations without differentiating long-range changes from short-range changes associated with the business cycle (see p. 342). Such misunderstandings prompted Denison and Poullier to begin the scholarly struggle which the book's 492 pages represent.

Two ideas are crucial to their explanation of why growth rates among developed nations differ: (1) reallocation of surplus farm labor, and (2) education.

The attention devoted to the exodus of farmers and to the education of the working force gives any student of economic development a reason to know about this book; it is this emphasis that gives the book its uniqueness, its relevancy, and its chance to number among the contemporary classics on economic growth. Denison's analytical approach to economic growth was developed in his first book, published in 1961 and entitled "The Sources of Economic Growth in the United States and the Alternatives Before Us" (Suppl. Paper 13, New York, Committee for Economic Development). In his second book he uses the same approach, adding the concept of comparison to his analysis. A look at U.S. growth rates compared with the growth rates of eight European nations was prompted by two questions that were plaguing Washington's economic policymakers: "Why had the economic performance of the American economy measured up so unfavorably against the economic miracles of Europe?" and "Will Europe's growth rates continue to surpass that of the United States?"

An entire chapter is devoted to the "Excessive Allocations of Labor to Farming and Self Employment." In it Denison responds to the first question:

> . . . the United States has curtailed excessive employment in agriculture about as much as any European country . . . . However, the large continental countries started in 1950 from a position where the waste from misallocation was much greater, and a reduction of this waste contributed much more to the 1950-62 growth rate of output per man in continental Europe than in the United States.

Denison estimates that the contribution to the 1950-62 growth rate of the shift from agriculture was 0.25 percentage point in the United States, but 0.65 in France, 0.76 in Germany, and 1.04 in Italy. He concludes that "this source consequently explains much of the difference in growth rates between the United States and Northwest Europe as a whole and among the individual countries" (p. 201-202, 215).

Denison's conclusions are especially credible because he has given careful attention to the methodological differences in national statistics and has apparently overcome most of them.

As Denison describes how the reallocation of farm labor occurred, explains how reallocation is related to growth rates, and estimates the contribution from this source in specific countries, the reader can retrace Denison's analysis of the question and the implications of his answer. Tables, generous in number and in detail, provide factual support for Denison's

words and serve as quantitative summaries of his concepts.

To the second question concerning future differences in these developed nations' growth rates, Denison responds first in terms of the immediate future: "So long as the opportunity to gain from reallocation of resources remains large, Western Europe as a whole should be able to obtain larger increases than the United States in national income per person employed . . ." (p. 342).

Then he responds in terms of the distant future, predicting that it will be a long time before U.S. levels of per capita output are reached by the Northwestern European nations because the United States has continued to exploit her available opportunities for growth. Specifically, the United States has exploited the opportunity to increase the quality of the labor force through education. "Educational background is a crucial determinant of the quality of labor. It conditions both the types of work an individual is able to do and his efficiency in doing them . . ." (p. 78).

In his first study of U.S. growth from 1920 to 1957, Denison traced 23 percent of the total economic growth obtained during that period to education. In this current study of the 1950-62 period, Denison estimates that this source "raised the average quality of American labor by 9 percent (or 0.7 percent a year) and contributed one-half a percentage point to the growth rate of national income. Improvement in the educational quality of the labor force was only half as great in Northwest Europe . . . the present tendency is for the gap to widen . . ." (p. 78). He concludes:

> This finding which I consider unambiguous and firmly based--that the education of the labor force has increased less, not more, in Europe than in the United States--is a major one . . . . Education is, therefore, likely to remain a factor operating towards widening the gap in income levels between the United States and Northwestern Europe (p. 101, 107).

International economists, presumably Denison's most important audience, will be disappointed by two weaknesses of this study. First is his admitted reluctance to offer anything but "experimental calculations" for the contribution made by a reduction in trade barriers. The experimental calculations arbitrarily establish a zero gain for the United States and a mere 0.8 percent of a total growth rate of 3.80 for Northwest Europe (p. 298, 300). The study ends just as the gains of Europe's relaxation in tariff barriers within EEC and EFTA begin.

Second, in the Epilogue for American Readers, Denison says:

> The contribution made by international investment should not be overlooked. If, in the future, American investment in Europe is impeded by restrictions imposed in response to the American balance of payments problem or by European opposition, it will be unfortunate for growth in both areas (p. 344).

Unfortunately, especially in light of current concern about U.S. investments abroad, Denison fails to provide substantial evidence in support of this statement.

Several questions about economic growth and growth-rate differences remain to be answered: Is education best quantified, as Denison does, in terms of hours spent in school? Is he justified in omitting all contributions of education obtained in commercial and trade schools and on part-time programs? What role has the demand created by Madison Avenue advertising techniques played in the growth of the economy? What contribution is made by the correct interrelation, balance, and harmony of the 23 sources Denison identifies?

In not answering these and other questions, Denison was aware of his own limitations and the limitations of present methods. Working within these limitations, Denison has endeavored to present a cogent, comprehensive analysis of "Why Growth Rates Differ." He has succeeded.

Ann Miller

Agricultural Development, Planning and Implementation; An Israeli Case Study

By Raanan Weitz and Avshalom Rokach. Frederick A. Praeger, New York. 404 pages. 1968. $20.

WHEN, IN 1966, J. Price Gittinger published his survey of "The Literature of Agricultural Planning," he stated: "By far the most serious lack in agricultural planning literature

is detailed, analytical case studies prepared by perceptive trained workers." The present study is a notable contribution to filling that lack.

Although Israel as a developing country is atypical from the point of view of size, available capital inputs, and quality of manpower inputs, a study of the planning and implementation of agricultural development in this microcosm can give us many insights into the magnitude and complexity of the development task.

For example, in planning the most advantageous use of limited land and water resources, European markets for high value export crops were intensively studied and projections of future demand and future competition in those markets were made. Probable price trends and the ability of Israeli products to meet competition, while at the same time providing rural residents with levels of living on a par with urban industrial workers, were postulated as considerations in decision making. Such studies led to specialization in citrus and deciduous fruits, winter vegetables, and dairy and poultry products. Continued reliance on imports for supplies of bread grains and feed grains became national economic policy.

In planning for the organization of agricultural production, large-scale factory farms using hired labor were considered as well as the collective (kibbutzim) and family farms. It should be of special interest to Americans to note that the ultimate decision, based on study and experience, favored the family farm. These are organized around village centers (moshavim) where most marketing and purchasing functions are carried out cooperatively. Regional centers to provide more sophisticated services for groups of villages were planned. Higher education, cultural centers, hospitals, processing facilities, agribusiness, and, eventually, industry, will not only provide goods and services to the farm sector but employment for surplus rural population.

As a chronicler of agricultural development in Israel, Raanan Weitz knows whereof he speaks. He has been associated with the Settlement Department of the Jewish Agency for 30 years and is now its head. Avshalom Rokach works with Weitz. The Settlement Department is responsible for planning and development of agricultural colonies in Israel. The agency nurtures the colonies and the colonists until they become economically viable and socially integrated into the national pattern. Then the new villages and towns become self-governing units receiving their government services from regular units of government such as the Departments of Agriculture, Health, and Education.

Although the authors mention a few cases of failures in settlement projects, they are only superficially analyzed and quickly passed over. Likewise production problems--such as a high proportion of unexportable "hollow" tomatoes--are treated as problems soon to be solved by the researcher. The authors are recounting a success story. Sadly, only small segments of their experience are transferable or even adaptable to today's developing countries within existing limitations of capital and human resources.

Jane M. Porter

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Suggestions for Submitting Manuscripts for Agricultural Economics Research

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3. NUMBER OF COPIES. Submit one ribbon copy and two additional good copies of the manuscript for review.

4. TYPING. Double space everything, including footnotes.

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6. FOOTNOTES. Number consecutively throughout the paper.

7. REFERENCES. Check all references carefully for accuracy and completeness.

8. CHARTS. Use charts sparingly for best effect. Include with each chart a page giving essential data for replotting.

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